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The Potentials of *Jatropha* Plantations in Egypt: A Review

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Abstract

Jatropha curcas **L. is one of the recently planted trees that utilizes wastewater in Egypt. It is not just because of its features, such as drought tolerance, rapid growth, and easy propagation, higher oil content than other oil crops, but also because of the Egyptian unique model which uses wastewater for planting *Jatropha* in the marginal desert land, which in turn represents an excellent opportunity to make use of such land. Moreover, this system provides a good way for reusing the treated sewage water, which itself represents an environment hazard. In addition, *Jatropha* plantations can be used in the future to be the base for the biodiesel production industry. This review tried to cover the current situation of *Jatropha* plantations in Egypt. To do so, the paper first reviewed the available land and wastewater resources, and then the potential EU biofuel market situation. Finally, it discussed the biofuel production potentials in Egypt.**

Keywords

Wastewater, *Jatropha*, Biofuel, Environment, Economics, Egypt

1. Introduction

As the world seeks a sustainable and green agricultural production on one hand, and seeks sufficient production which can support food security for the growing world population on the other hand, three major problems appears: climate change, pollution and resources limitations. In Egypt, for example, more than 90% of the total land area is marginal desert land [1], and around 80% of its limited fresh water amount used by agricultural sector [2], one can see that the limitation of its water resources represents a huge challenge appears in front of any attempt to increase the agricultural land amount in the future. Conversely, as population increases, waste-

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water represents a threat to both of environment and population, and at the same time it also represents a valuable resource which can be used for the sake of the agricultural expansion plans and making use of the marginal desert land. Inappropriately, and according to the health regulations, the treated wastewater cannot be used to irrigate all agricultural crops and plantations, instead it's just used to irrigate a certain kind of trees and crops. Because of that, Egyptian government implemented a wide range of new projects aiming at expanding the green stretch in the desert by introducing forests plantation (man-made forests) which making use of treated sewage water. All of these new projects under one umbrella are called "The National Programme for Safe Use of Treated Sewage Water for Afforestation" [3]. As implementation of this program, *Jatropha* was planted in many demonstration areas and it really shows excellent results [4], so the idea of stretching the *Jatropha* plantations to all over available appropriate land area is worthy to study. Furthermore, we can take into consideration the economic value for biodiesel production from *Jatropha* seeds and all other socio-economic effects that may occur by adopting such industry.

2. *Jatropha* around the World

Jatropha curcas appears to be an ideal plant to produce second-generation biofuels, *i.e*. manufactured from agricultural or forest residuals and from non-food crop feedstock. *J. curcas* is suitable for cultivation in marginal and idle lands. Cultivation of the plant for biodiesel production does not induce land-use change, since *J. curcas* grows in degraded lands, and as a non-food feedstock, it does not compete with agricultural production. A by-product of oil extraction, e.g., seedcake, produces organic fertilizer through composting that can eventually be used as organic manure. This might reduce N_2O emissions due to nitrogen-based fertilizers. Finally, *J. curcas* could represent an opportunity for poor countries to benefit from the growing demand for biofuels [5]. *Jatropha curcas* L. is a vigorous, drought- and pest-tolerant plant and unpalatable by animals. It is planted in tropical countries principally as a hedge, protecting cropland from the cattle, sheep and goats. *Jatropha* seed and other plant parts have been used for oil, soap and medicinal compounds. *Jatropha* is popularized as unique candidate among renewable energy sources due its peculiar features like drought tolerance, rapid growth, and easy propagation, higher oil content than other oil crops. The seed yield reported for *Jatropha* varies from 0.5 to 12 ton $year^{-1} \cdot ha^{-1}$ depending on soil, nutrient and rainfall conditions, and the tree has a productive life over 30 years. The seeds contain 30% - 35% oil that can be converted into good quality biodiesel by trans-esterification [6]. *Jatropha* was planted on an estimated 900,000 ha around the world, 760,000 in Asia, 120,000 in Africa and perhaps 20,000 in Latin America. This chimes with what we have learned anecdotally: that up to 1 million ha were planted in a period of 5 years or more to 2010, but of which as much as 800,000 ha had been planted in environments unsuited to commercial cultivation, much of it in India in the form of small holder & out grower plantings. It is generally accepted that some 800,000 ha was planted out in India, 200,000 ha in Indonesia and other Asian countries including Myanmar and around 100,000 ha in Africa. Some 70% is estimated to have been planted by small holders. Anecdotal reports indicate that around 200,000 ha have been planted out in suitable areas, again spread over India, Indonesia and Africa principally [7].

Jatropha also has many other uses and benefits which increase its value for rural African communities. One of the reasons for interest in *Jatropha* is its potential for growth in harsh conditions. *Jatropha* has already been grown or is being grown in many parts of Africa and requires minimal input and is also easy to propagate [8]. The *Jatropha* System is an integrated rural development approach. By planting *Jatropha* hedges to protect gardens and fields against roaming animals, the oil from the seeds can be used for soap production, for lighting and cooking and as fuel in special diesel engines. In this way, the *Jatropha* System covers 4 main aspects of rural development:

- Promotion of women (local soap production);
- Poverty reduction (protecting crops and selling seeds, oil and soap);
- Erosion control (planting hedges);
- Energy supply for the household and stationary engines in the rural area.

The obvious advantage of this system is that all the processing procedure, and thus all added value, can be kept within the rural area or even within one village. No centralized processing (like the cotton industry) is necessary [9].

3. Biodiesel Consumption

Development of biofuels from renewable resources is critical to the sustainability of the world's economy and to slow down the global climate change. Currently, a significant amount of bioethanol and biodiesel are produced as biofuels to partially replace gasoline and diesel, respectively, in the transportation sector worldwide. However, these biofuels represent a tiny portion (<4%) of the total fuels consumed. Furthermore, bioethanol is produced predominantly from sugarcane and corn, and biodiesel from crop and plant oils [10]. The EU has dominated world biodiesel, whereas the US and Brazil have led fuel ethanol production. World net biofuel trade reached 120 - 130 PJ in 2009 and was directed towards the most lucrative markets. For biodiesel, this has been the EU whose imports rose to 92 PJ in 2008 and remained at 70 PJ in 2009 [11]. The world price of biodiesel (Central Europe FOB) increased to $4.82 per gallon in 2008, driven by high demand as EU countries attempted to achieve their biofuel targets and because of high crude-oil prices. Expanded production in Argentina and Brazil led to a temporary price decline, to $4.40, in 2009 and a sharp increase in exports before the start of the countries' B5 mandates. However, the world price will increase to $6.00 per gallon by 2017, driven by higher demand from the EU. World net trade doubles to 607 million gallons over the next decade, driven mainly by strong EU demand [12] (**Figure 1**).

Currently, the EU has the world's most developed biodiesel industry. Production was about 3.3 billion gallons in 2007, and it will reach 4 billion gallons by 2021. Pushed by the biofuel target, domestic consumption continues to grow during the outlook period, reaching 5.0 billion gallons by 2021. Net imports increased rapidly, from 661 million gallons in 2007 to 824 million gallons in 2014 as a sizeable volume of biodiesel was delivered from Argentina and Brazil. Net imports of EU are expected to hit around 1billion gallons at 2021 [13]. (**Table 1**)

African countries, such as Sudan, have recently started exporting to the EU market, joining countries with a longer history of exports such as Egypt, Malawi and Zimbabwe, with preferential access to EU markets. African countries have excellent potential to increase their exports, assuming that trade reforms and the conditions for investment in Africa continue to improve, this trend seems likely to persist [14]. One more thing to mention, the advantage of the location of Egypt is near EU market, which considers short distance transportation we can neglect the transportation prices changes. As for short distance transport, such as from the Baltic to Sweden, sharp increases in prices may not be a major factor. However, for long-distance transport, such as from Canada to Europe or Australia to China, where shipping is a major component of landed cost, major shipping price increases may be sufficient to cause a source of biomass supply to drop completely out of the market [15].

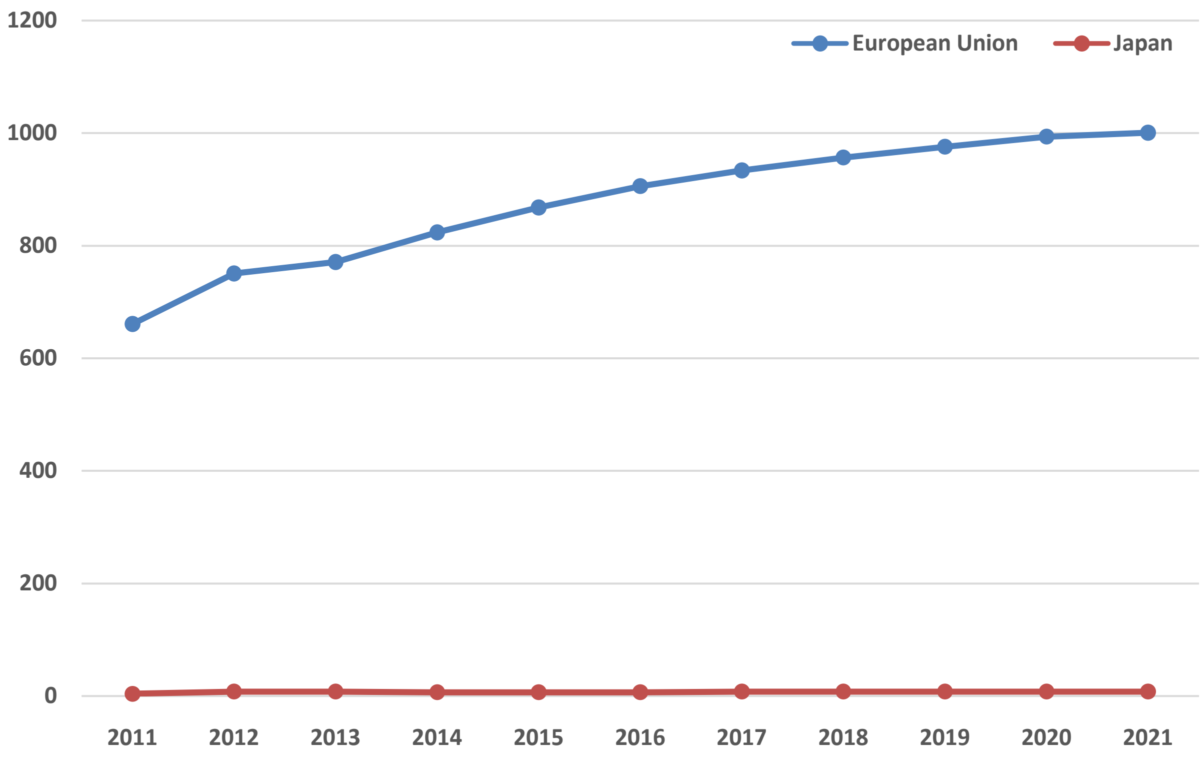

Figure 1. European Union & Japan biodiesel imports (million gallons). Source: [13].

Table 1. European Union biodiesel production and consumption (million gallons). Source: [13].

Year	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Production	3079	3191	3277	3337	3422	3522	3613	3712	3807	3912	4022
Consumption	3731	3941	4046	4160	4290	4427	4547	4668	4783	4906	5023
Net Trade	−661	−751	−771	−824	−868	−906	−934	−957	−976	−994	−1001

4. Land & Water Resources in Egypt

More than 90 percent of Egypt is desert. The total agricultural land base totals about 3.5 million ha (8.4 million feddan) represents about 3.5% of the total area, which is about 1 million·km^2 (240 million feddan). Of this agricultural land, 3,276,000 ha (7.8 million feddan) lie within the Nile Basin and Delta, and the remaining 210,000 ha (500,000 feddan) are rain-fed or in the oases. Of the total area of the Nile Basin and Delta, about 2,268,000 ha (5.4 million feddan) are old lands, the remaining 1,008,000 ha (2.4 million feddan) are new reclaimed lands [1] [16].

In the meanwhile, The River Nile is the main source of water for Egypt with an annual allocated flow of 55.5 Bm^3/yr. under the Nile Waters Agreement of 1959. Internal renewable surface water resources are estimated at 0.5 Bm^3/yr. This brings total actual renewable surface water resources to 56 Bm^3/year. Internal renewable groundwater resources are estimated at 1.3 Bm^3/yr. The overlap between surface water and groundwater is being considered negligible, the total actual renewable water resources of the country are thus 57.3 Bm^3/yr. The Nubian Sandstone aquifer located under the Western Desert is considered an important groundwater source, but this is fossil groundwater. The main source of internal recharge is percolation from irrigation water in the Valley and the Delta. All drainage water in Upper Egypt, south of Cairo, flows back into the Nile and the irrigation canals; this amount is estimated at 4 Bm^3/yr. Drainage water in the Nile Delta is estimated at 14 Bm^3/yr. Treated municipal wastewater in 2001/02 was estimated at 2.97 Bm^3/yr. There are several desalination plants on the coasts of the Red Sea and the Mediterranean to provide water for seaside resorts and hotels; total production in 2002 was estimated at 100 million·m^3. Estimates of the potential of non-renewable groundwater in the eastern and western deserts, mainly from the Nubian Sandstone aquifer, vary from 3.8 Bm^3/yr. to 0.6 Bm^3/yr.; the latter estimate is defined as an indicator of exploitability over a period of time, where the time is not given. Total water withdrawal in 2000 was estimated at 68.3 Bm^3. This included 59 Bm^3 for agriculture (86%), 5.3 Bm^3 for municipalities (8%) and 4.0 Bm^3 for industry (6%) as displayed in **Table 2** [2].

The Government of Egypt (GOE) continues to invest heavily in expanding the cultivated area, aiming to add another 3.4 million feddan of cultivated land by the year 2017 in order to secure food for the rapidly increasing population [17]. However, according to the Food and Agriculture Organization of the United Nations estimates, the average needs of agricultural land from water in arid and semi-arid areas—which Egypt located in—should not be less than 5000 m^3/feddan/year for keeping this land away from salinization and loss, because of the warm climate that causes high rate of water evaporation from the land surface. And therefore the amount of water allocated to the agricultural sector in Egypt can hardly used to irrigate areas ranging from 10 to 11 million feddan though about 8.4 feddan of it have already planted and therefore the agricultural expansion under the current water resources can hardly add from 2 to 2.8 million feddan to the current agricultural land, which to be as a total about 11 million feddan [16].

Also it is worth mentioning that the availability of renewable water resources in Egypt has dropped from 2189 m^3/capita/year in 1966 to 1035 m^3/capita/year in 1990. With the current population growth rate, it will even drop more to 536 m^3/capita/year by the year 2025, if the share of Egypt from Nile waters remains as it is today (55.5 BCM) and levels of per capita consumption are maintained. Various demands for freshwater are exerting excessive pressure on the available water supply. In a nutshell, the strategic problem Egypt confronts is that its renewable water supplies cannot be expanded (and with the quality issues, available water suitable for some purposes may in fact decline), while at the same time population is growing and the economy is expanding, with associated increases in water requirements. By 2017, the National Water Resource Plan estimates that total water requirements will exceed 90 BCM [18].

5. Wastewater Status

Wastewater is the only source of water that increases with the time as population and their activities increase.

Table 2. Water availability and water use in Egypt (2000). Source: [2].

Water Input	Million m^3/yr	Water Use	Million m^3/yr
Renewable Surface Water Resources	56,000	Agriculture	59,000
Renewable Ground Resources	2300	Domestic	5300
Reuse of Agricultural Drainage Water (Return Flow to Rivers)*	4840	Industry	4000
Reuse of Groundwater (Seepage from Agriculture)*	6127		
Reuse Treated Wastewater	2971		
Desalinated Water	100		
Use of Fossil Groundwater (Non-Renewable Water)	825		
Total	**73,163**	**Total**	**68,300**
Navigation & Hydropower			**4000**

*Total water returning from agriculture was about 18 km^3, of which about 12 km^3 was return flow to rivers and 6 km^3 seepage to groundwater.

And to make use of this source, the Holding Company for Water and Wastewater (HCWW) was established by presidential decree No. 135/2004 in 2004. The purpose the Holding Company set by a Presidential Decree is to purify, desalinate, distribute and sell drinking water and collect, treat and safely dispose of wastewater, either itself or through affiliate companies [19] [20]. Egypt's Holding Company for Water and Wastewater owns and operates all of Egypt's 372 municipal wastewater treatment plants, treating an average of 10.1 million m^3/d of sewage [21]. Although sanitation covers more than 95% in urban areas of Egypt, it still covers less than 15% in rural areas and the rest of the rural areas still use septic tanks, and latrines [22]. It estimates that around EGP80 billion ($13 billion) of investment in wastewater collection and treatment would be needed to achieve full coverage for the countryside [21]. **Table 3** below presents the production capacity and investment in wastewater projects over the period of time and as expected until year 2012 [23].

It's a big investment for a developing country such as Egypt, but since the untreated sewage can represent a threat to the public health and the environment in general, it has to be done and a small drop of fecal matter can contain millions of microorganisms of many types, some of which are pathogenic. Microbial pathogens in raw or inadequately treated sewage can cause illnesses ranging from temporary stomach cramps to life-threatening conditions such as inflammation of the heart. While, for the healthy population, most of the illnesses resulting from exposure to inadequately treated sewage are relatively minor (respiratory illness; ear, nose or throat irritation; gastroenteritis), they can become serious in more vulnerable populations, including pregnant women, young children, the elderly, and people with suppressed immune systems (such as people with HIV, transplant recipients, and cancer patients) [24].

However, the current amount of collected wastewater in Egypt is about 6.5 Billion·m^3/yr., of which about 56% (3.65 Billion·m^3/yr.) is treated, and the rest of wastewater which around 2.85 Billion·m^3/yr. is not treated. Anyway, use of treated wastewater has become increasingly important in water resources management for both environmental and economic reasons. Wastewater use in Egypt is an old practice. It has been used since 1930 in sandy soil areas like Al-Gabal, Al-Asfar and Abou Rawash, near Cairo. Interest in the use of treated wastewater, as a substitute for fresh water in irrigation, has accelerated since 1980. Currently, the treated wastewater divided into two types, the first is primary treated and it's about 20% of the total treated wastewater about 0.73 Billion·m^3/yr. and the second is secondary treated about 2.92 Billion·m^3/yr., but only 0.7 Billion·m^3/yr. of treated wastewater is being used in irrigation, of which 0.26 Billion·m^3/yr. (secondary treated) and 0.44 Billion·m^3/yr. (primary treated) to cultivate forests & some crops. The rest amount of the treated wastewater which about 2.95 Billion·m^3/yr. is pumped to drains & canals in Cairo & Delta [18] [22].

Wastewater has been used to support the agricultural production in many countries such as USA, Germany, India, Kuwait, Saudi Arabia, Oman, Jordan and Tunisia. Several investigators indicated the beneficial role of wastewater in increasing crop yields without or with minimal risks to the plant, soil, groundwater and health [25]. It is generally accepted that wastewater use in agriculture is justified on agronomic and economic grounds but care must be taken to minimize adverse health and environmental impacts [26]. According to this fact the Egyptian government published "The Egyptian Code for the Reuse of Treated Municipal Wastewater in Agri-

Table 3. Production capacity and investment in wastewater projects. Source: [23].

Item	Production Capacity (1,000,000 M^3/D)	Average Per Capita Share (L/D)	Investment Implemented (LE Billion)
Till 1982	1.1	25	0.8
Till 2007	11	150	40
Till 2012	28	230	54

culture" and The code was approved by Ministerial Decree No. 171/2005, Ministry of Housing. The code regulates and classifies plants and crops Irrigable with treated municipal wastewater as **Table 4** illustrates [4].

Also from **Table 5**, we may note that C is primary treatment, B is secondary treatment and A is advanced treatment, and these grades determined as **Table 4** shows.

However, expansion of treated wastewater reuse in the region is linked to a number of issues and constraints. The high cost of treatment and management of reclaimed wastewater is one of the major limitations facing the weak economy of most countries. Unclear polices, institutional conflicts and lack of regulatory frameworks constitute other important constraints that hinder implementation and proper operation of wastewater reuse projects [28].

6. Energy in Egypt

Over the years, the power sector has always played a substantial role in enhancing economic development in Egypt via securing the domestic energy demand for electricity. Limited primary energy resources are available in Egypt with varying potentialities. The most important of these resources are oil, natural gas, and hydropower. In addition, renewable energy resources, particularly solar and wind, have a good potential [29]. In Egypt, crop residues are considered to be the most important and traditional source of domestic fuel in rural areas. These crop residues are by-products of common crops such as cotton, wheat, maize and rice. The total amount of residues reaches about 16 million tons of dry matter per year. Cotton residues represent about 9% of the total amount of residues and the materials are mainly comprised by cotton stalks, which present a disposal problem. The area of cotton crop cultivation accounts for about 5% of the cultivated area in Egypt [30]. Egypt's energy sector, specifically its electricity, oil and natural gas subsectors, is a large, important and promising part of the national economy. Egypt faces the challenges of growth in population, energy demand, and the energy production needed to meet its modern development goals. The economy is energy-intensive, especially the manufacturing and tourism components that together represented about 25 percent of GDP in recent years [31]. Egypt is the largest oil and natural gas consumer in Africa, accounting for more than 20% of total oil consumption and more than 40% of total dry natural gas consumption in Africa in 2013. Energy subsidies, which cost the government $26 billion in 2012, have contributed to rising energy demand and a high budget deficit [32] (**Figure 2**).

In 1986, Egypt's New & Renewable Energy Authority (NREA) was established to act as the national focal point for expanding efforts to develop and introduce renewable energy technologies on a commercial scale. Since then, a number of governmental organizations have been set up to help promote and develop policies to encourage the growth of the renewable energy industry. Egypt's present energy strategy (adopted by resolution of the SCE in February 2008) aims at increasing the share of renewable energy to 20 percent of Egypt's energy mix by 2020 [33].

7. *Jatropha* in Egypt

In Egypt, There is particular interest in using forest plantations as a means of addressing a number of key environmental priorities, including the safe use of primary treated municipal wastewater and for combating desertification. These environmental aims are also compatible with biomass feedstock production for possible future ligno-cellulosic ethanol production [34]. As a start, more than 160,000 feddan (67,200 ha) are available for plantations [35]. Mainly all of this area is marginal desert land and for now as a start around 88,000 feddan (36,960 hectare) is allocated to the Holding Company for Water and Wastewater for reuse projects in different governorates, around 11,000 feddan (4620 hectare) of the total allocated area already cultivated with various plantations [22]. **Table 6** shows different locations of treated wastewater reuse.

Table 4. Egyptian code for plants & crops irrigable with treated wastewater. Source: [4].

Grade	Agricultural Group	
A	G1-1: Plants and trees grown for greenery at tourist villages and hotels. G1-2: Plants and trees grown for greenery inside residential areas at the new cities.	Grass, Saint Augustine grass, cetaceous plants, ornamental palm trees, climbing plants, fencing bushes and trees, wood trees and shade trees.
B	G2-1: Fodder/Feed crops	Sorghum sp.
	G2-2: Trees producing fruits with epicarp.	On condition that they are produced for Processing purposes such as lemon, mango, date palm and almonds.
	G2-3: Trees used for green belts around cities and afforestation of high waysorroads	Casuarina, camphor, athel tamarix (salt tree), oleander, fruit-producing trees, date palm and olive trees.
	G2-4: Nursery plants	Nursery plants of wood trees, ornamental plants and fruit trees
	G2-5: Roses & cut flowers	Local rose, eagle rose, onions (e.g. gladiolus)
	G2-6: Fiber crops	Flax, jute, hibiscus, sisal
	G2-7: Mulberry for the production of silk	Japanese mulberry
C	G3-1: Industrial oil crops	Jojoba, castor-oil plant, and *Jatropha*
	G3-2: Wood trees	Kaya, camphor and other wood trees.

Table 5. Wastewater treatment grades. Source: [27].

Treatment Grade Requirements		A	B	C
Effluent limit values for BOD and SS	BODs	<20	<60	<400
	SS	<20	<50	<250
Effluent limit value for fecal coliform and nematode cells or eggs (per liter)	Fecal coliform count[2] in 100 cm^3	<1000	<5000	Unspecified
	Count of nematode cells or eggs per liter	<1	<1	Unspecified

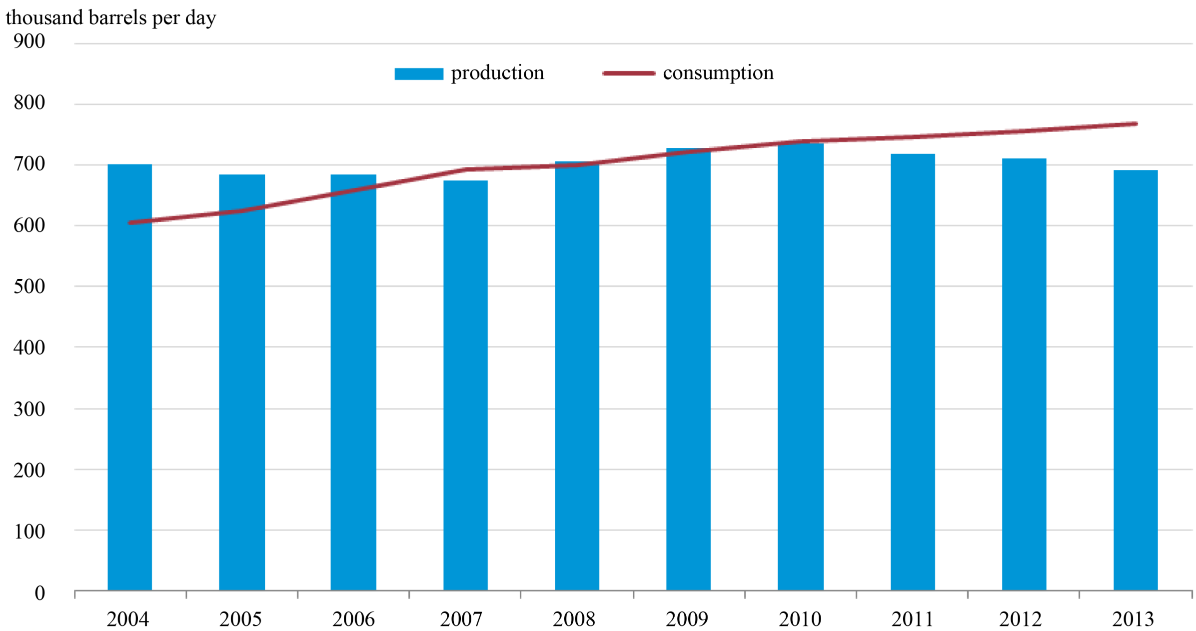

Figure 2. Petroleum and other liquids production & consumption in Egypt.

Many plants and crops cultivated in the above mentioned area and *Jatropha* is one of them (**Table 6**). The *Jatropha* experiment started in Egypt in 1997 on small scale, using *Jatropha curcas* seed imported from India. Promising results prompted the Egyptian Government to plant this species using seed from India on a wider scale, including the establishment of 42 hectares of *Jatropha* in 2001, irrigated by treated sewage water (drip irrigation). All desert areas of Upper Egypt governorates and in the New Valley are considered potentially suitable for *Jatropha* plantations. Such marginal land which has been planted with *Jatropha* in Egypt presently covers 844 hectares [36]. And it distributed over many areas as **Figure 3** shows.

Table 6. Locations of treated wastewater reuse. Source: [4].

Governorate*	WWT Plants Total Capacity ('000 cu MT)	Total Available Land Area (Feddan)	Designated
6 October	500	53,800	Yes
Alexandria	1373	70,000	
Beheira		625	
Matrouh	25	3007	Yes
Menoufiya	45	1600	Yes
North Sinai	50	4000	only 500
South Sinai	775	1019	Since 1999
Ismailia	100	1060	Since 1991
Beni Sewaef	124	2163	Since 2005
Menya	240	7000	
Fayoum	92	345	Since 2008
Assiout	226	12,467	Yes
New valley	84	4711	Since 1963
Sohag	284	18,325	Since 1998
Qena	249	17,021	Since 1999
Aswan	107	2469	Yes
Luxor	46	2086	Yes
Red Sea		2994	Since 1999
Total		**204,692**	

*Governorates only have available lands for reuse.

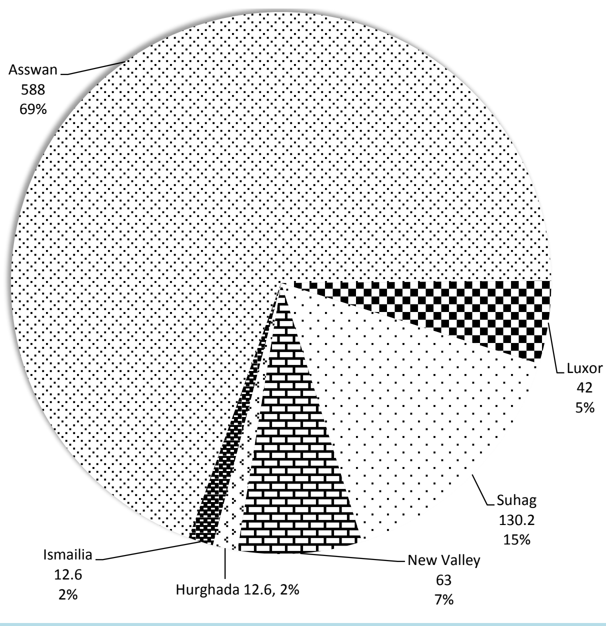

Figure 3. Land area cultivated by *Jatropha*. Source: [36].

In 2008, a feasibility study was made about *Jatropha* plantations in Luxor by Dr. Imam El Gamassy, and among his results on the national level was that *Jatropha*, as a source of biofuel, must be part of the renewable energy strategy in Egypt. Plans to promote its use should be taken seriously. And all expansion areas for *Jatropha* plantation must be near treated wastewater plants in the desert or on marginal lands. Its cultivation must be totally prohibited on agricultural lands. Moreover, *Jatropha* cultivation should be a government-controlled activity to protect agricultural lands from being used, as they might be if left under private sector management. And at last, the *Jatropha* biodiesel industry should be planned and established as a national fuel resource as the traditional ones (oil and gas) [37].

In 2009 Dr. Kenneth Swanberg made a study about "Alternative Crops with Potential for The Reuse of Treated Wastewater in Egypt". In his study, he tried to identify which one or combination of the crops mentioned earlier might have possibilities for generating significant financial returns for the use of treated wastewater in the allocated area which mentioned in the previous section. One of his key finding was that *Jatropha curcas*, oil seed crop that is known to be one of the more promising bio-diesel fuel oil crops. *Jatropha* is grown at several sites, with varying degrees of productivity. However, new plantings at Luxor and Abu Rawash look extremely promising, with earlier than expected yields. With the higher and earlier yields, *Jatropha* becomes an economically viable crop. In-country processing of bio-diesel is projected and highly recommended in order to capture the full value-added processing income of this crop. He also said, "The real opportunity for Egypt is to grow *Jatropha* using treated wastewater. Since *Jatropha* is not edible, and in fact is used as a deterrent to animals in hedgerows, and in some instances as pesticide, it is perfectly suited for use of wastewater. In addition, the wastewater is nutritious for the plant, with nitrogen and other chemicals, and at the wastewater sites, there is plenty of water to be disposed of on the plants, assuring that they will be amply watered. Some of the initial test sites for *Jatropha* took 2 years to grow fruit, but the recent plantings have borne fruit within the first year. This is very promising." [4].

8. Potentials of *Jatropha* Plantations

After this review discussed many resources and aspects related to *Jatropha* plantations in Egypt, now we can conclude the opportunities for *Jatropha* plantations in Egypt and biodiesel production in the following points.

- The European Union—the world's largest biofuel market—they target to reach 10% for the use of renewable energy in road transport fuels by 2020 [38], and such policy is very promising because it will give the chance to the Egyptian biodiesel to compete in the EU market, especially if we take into consideration the distance between the two markets.
- The plantation of *Jatropha* also works for Clean Development Mechanism (CDM) promoted by the Kyoto Protocol. For example, under the Kyoto Protocol, Japan needs to reduce its greenhouse gas (GHG) emissions about 12 billion tons between 2008 and 2012, which is 6% of the 1990 emission level. However, the actual GHG emissions in 2006 exceeded more than the double of the allowance. The former Prime Minister Abe appealed to reduce 50% of the world GHG emission by 2050, but Japan should prove its responsibility and reliability with Kyoto treaty at first before the high and long term promising. This unique Egyptian biofuel model—biofuel from wastewater and waste land—can be a good opportunity for a Japanese contribution to the global warming mitigation outside of Japan. By our rough assumption for the Egyptian model, 1 million hectors of *Jatropha* plantation is expected to produce 1 million ton of BDF. This 1 million ton of BDF usage would reduce 2 million tons of CO_2 emission. Annually, a value of 28 million US$ market would be delivered. The Egyptian actual profits from the carbon trading would be one-half or one-third of the expected value [39].
- *Jatropha* plantations could cause some impacts on the society as well, as most of the potential suitable area for *Jatropha* plantations located in Upper Egypt, which is less developing, more rural and poorer than any other area in Egypt, moreover most of labor from this area migrates to Lower Egypt [40] which is represent major problem now. Also the biodiesel production can offer more job opportunities and make overall developing in this area.

9. Conclusion

In 1997, the Egyptian government started *Jatropha* plantations experiment as part from "The National Program for Safe Use of Treated Sewage Water for Afforestation" which aims to expand the green stretch in the desert by introducing forests plantation (man-made forests) and to produce high economic value trees by making use of treated sewage water. Moreover, giving that more than 90 percent of Egypt is desert [1], and that only only 0.7 Billion·m^3/yr. out of 3.65 Billion·m^3/yr. of the treated wastewater is being used in irrigation [18]. One the other hand, the River Nile is the main source of water for Egypt with an annual allocated flow of 55.5 Bm^3/yr [2]. According to these facts, we can see the opportunity of *Jatropha* plantations & biodiesel production and we know that *Jatropha* gives higher and earlier yields in Egypt [4]. In addition, the increase in EU imports of biodiesel [13] can create a huge market for the Egyptian biodiesel in the future.

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